Final Report

NCPTT Project: Novel Electronic Technology for Real-time Detection of Trespass at Archeological Sites

Project: P15AP00091

SUNY ESF / Irbis Solutions Inc.

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Project Contacts:

James P. Gibbs, Ph.D.
State University of New York College of Environmental Science and Forestry
247 Illick Hall, 1 Forestry Drive, Syracuse, NY 13210 USA
Telephone: (315) 470-6764; Fax: (315) 470-6934; Skype: jamesgibbs1; Email: jpgibbs@esf.edu

Sean Burnett

Irbis Solutions Inc.
5038 Benton Court, Victoria BC V8Y2Z5 Canada
Telephone (250) 888-4367; email: sean@wildlifeintel.com

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Project Purpose

The purpose of this study was to trial satellite-based anti-trespass technology developed for wildlife conservation to determine its suitability for archeological and cultural sites.

Objectives

Vandalism and looting are major threats to cultural resources on U.S. National Park Service properties. Novel electronic technology now exists that can inexpensively report in real-time on trespass at vulnerable sites in remote areas. The key objective of the project was to understand the fit and feasibility of satellite-based anti-trespass technology by training staff at participating sites to install equipment and monitor their experiences. Another objective was to adapt the technology to better suit the archaeological and cultural site context. Finally, an objective was to assess the experiences of trials and determine the potential of such technology to protect archeological and cultural sites.

Methods

At the start of the evaluation study the project team sought volunteers at archeological and historic cultural site organizations who were willing to conduct trials of the anti-intrusion system. The basis of co-operation (formalized as a Memorandum of Understanding with one park) was as follows:

Participating organizations would provide the following:

- Interviews during the course of a site visit to discuss challenges with vandalism and looting
- Follow up email and teleconferences as needed
- Participation in installation and monitoring of pilot sites
- Feedback on the technology
- Suggestions for improvement
- Review of the project write-up and lessons learned

SUNY-ESF and Irbis Solutions would provide the following:

- Trespass monitoring systems
- Two years of Iridium satellite data subscription for each
- Project assessment and documentation

On completion of the project, the parks could keep and continue to use the equipment.

The project team provided training and support during the course of the project. During these training sessions, participants were asked how the technology could be used and how it could be adapted to better suit archaeological and cultural site protection.

Some of these adaptations were designed and developed quickly enough to trial within the timeframe of the project, while others required extensive research and development and were completed at the project end date. Participating parks were given the option to upgrade their systems at the end of the project should they continue to use the technology. Parks were also given the option to continue use of the technology after the two years satellite subscription had elapsed (provided at cost by Irbis Solutions Inc.).

At the end of the project, participants were invited to a webinar to review the project and discuss their experiences. This was preceded by an on-line survey to collect project outcomes.

Results

Participants

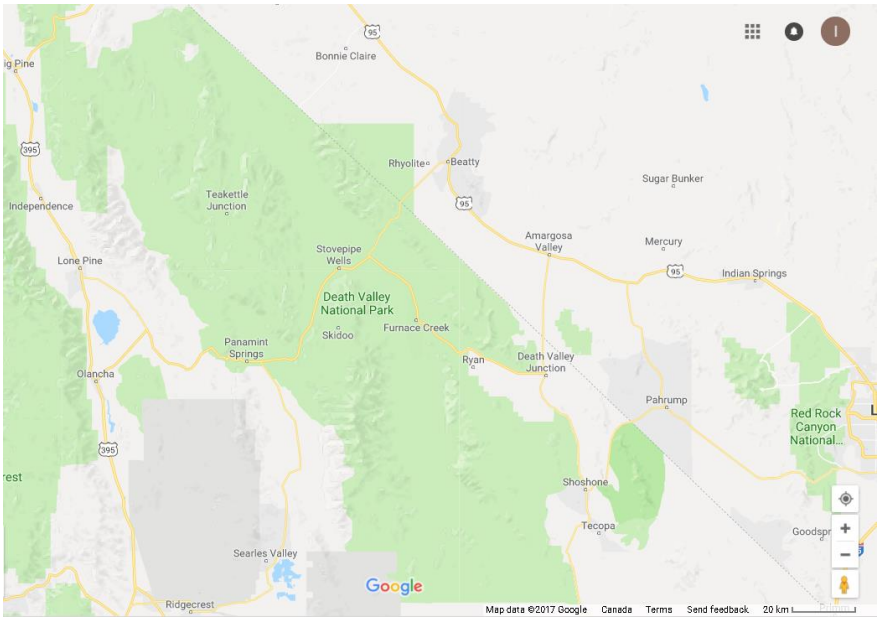
Members of the project team met with staff from five parks who volunteered to become part of this NCPTT sponsored study. In total, nine systems were sent out for evaluation.

Park	Study Contact	Site Visit Date
Death Valley National Park	Wanda Raschkow, Park Archaeologist	March 23-24, 2016, October 24, 2016
Bandelier National Monument	Jeremy Sweat, Chief, Resource Management / David Sutherland, US Park Ranger	March 21-22, 2016
Verde Valley Archaeology Center (Official Nonprofit Partner of the National Park Service for Montezuma Castle and Tuzigoot National Monuments)	Kenneth Zoll, Executive Director	March 19, 2016
Home of Franklin D. Roosevelt NHS	David Hayes	Dec 12, 2016 Teleconference training

Park Experiences

Death Valley National Park

The project team met in person with Death Valley staff on two occasions. The first meeting was across March 23 and 24. Attendees included Wanda Raschkow (Park Archaeologist), Joshua Vann (Supervisory Ranger) and Andrew Riordan (Park Ranger).



Meeting participants received an overview of the project, of the technology, and training in using the system.

At the end of the meeting, attendees successfully set up and tested the equipment. During the second day, the project team, the Park Archaeologist and Park Ranger installed a break beam sensor system at the base of a gated road leading to Scotty's Castle – an abandoned mansion from the 1930's which was recently subject to vandalism. Subsequently, a vehicle sensor was installed at a second road entrance to the Castle.

During the course of the overview and training, several questions issues arose and their resolution was integrated into training materials and website on-line help.

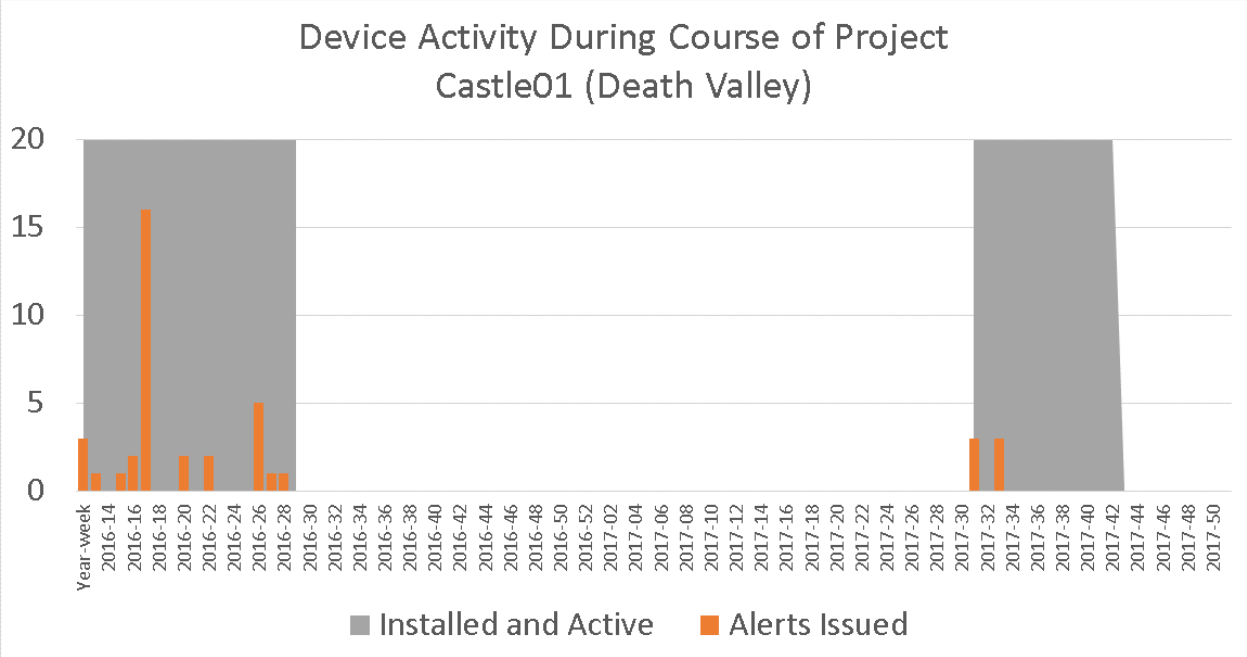
Question	**Answer**
How deep should the vehicle sensor be buried?	About 6 inches, cover with fine dirt instead of sharp rocks
How quickly are alerts delivered?	Usually under 10 minutes and sometimes as quickly as 1 minute
Can the road sensor be placed inside a PVC tube for additional protection?	Yes
What will happen if the device is tampered with?	If a sensor is cut or damaged, the system will send one alert. Subsequent check-ins will indicate that the sensor is offline

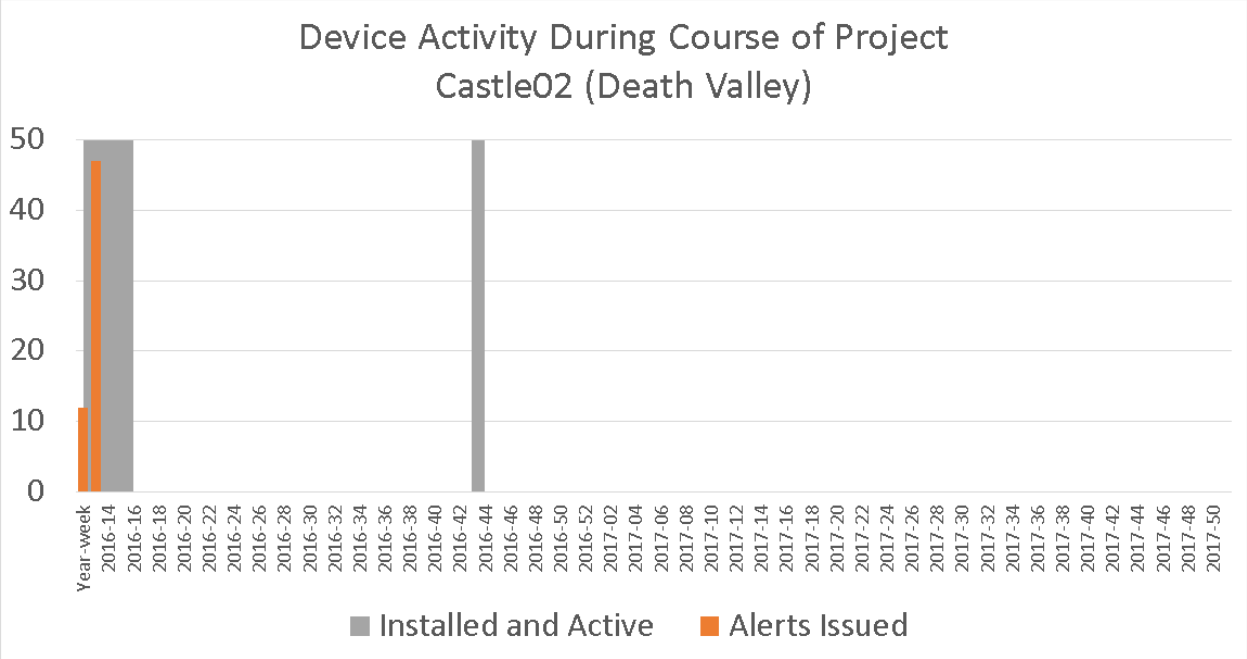
Death Valley NP participants identified potential enhancements to the system including: the need to suspend alerts during certain times of the day e.g. during visiting hours; the need to give distribution destinations (such as InReach and phone numbers) a nickname, and; wireless sensors to cover large areas such as a 2 mile long burial site.

Other discussion included the restrictions on installation digging in archaeological sites and related, non-archaeological activities such as marijuana grow ops in back country. Death Valley NM participants cited the on-going need for more law enforcements staff to increase patrols. They did not see much advantage to footfall sensors because of the restrictions on digging and because of the wide access points. There was concern that the devices might not operate in extreme heat because Death Valley has the highest recorded temperatures on Earth.

The project team accompanied the park archaeologist and law enforcement staff for the two installations.

During the subsequent several months, Death Valley received system check-in and alert messages for two of their three systems (the third was not installed):



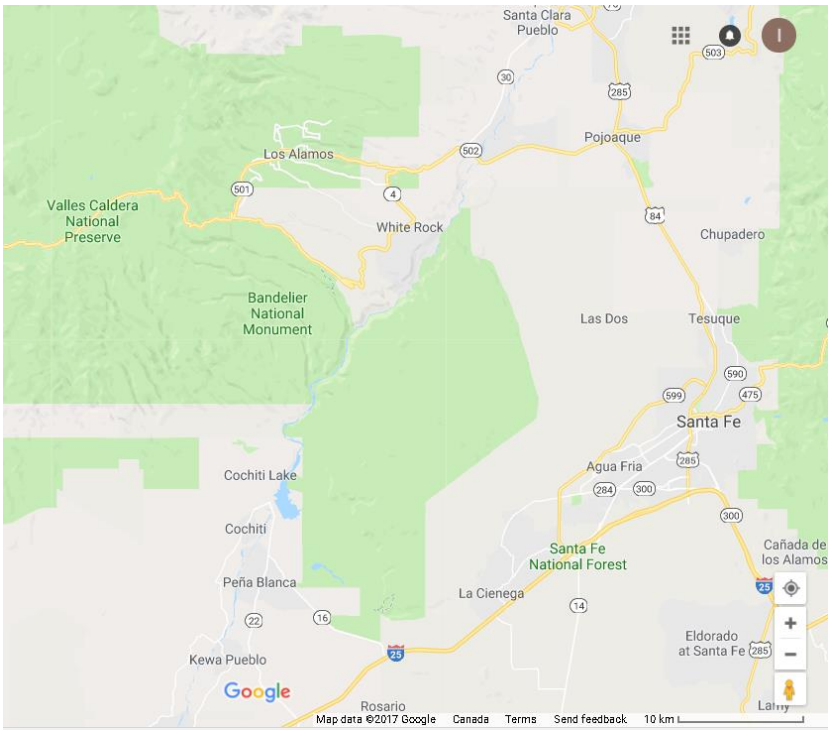


The park encountered issues during the two years of deployment. First, the sub-optimal break beam installation (at knee level) resulted in many alerts at 8 pm each night. The best accepted theory is that coyotes or similar animals were more active at that time in Death Valley and were exploring the sensor, causing triggers. In September, 2016 a vehicle sensor based system went offline. It was found that the device had been dug up, smashed inside, then replaced as if it were untouched. The project team subsequently replaced that system.

On a second site visit, the project team had an opportunity to check in with Death Valley NP archaeologist Wanda Raschkow. Of note was that in controlled circumstances, the vehicle sensors "…catches them every time…" but that law enforcement staff often did not have time to investigate alerts. At that time, Death Valley NP systems were upgraded to the latest system firmware.

Bandelier National Monument

The project team met in person with Bandelier National Monument staff on Monday, Mar 21, 2016 and Tuesday, Mar 22, 2016. Attendees included Jeremy Sweat (Chief, Resource Management), Dennis Milligan (Chief Ranger, Law Enforcement), and Jamie Civitello (Cultural Resources Program Manager and Park Archeologist) and other law enforcement staff.



The project team gave Bandelier National Monument staff an overview of the project, of the technology, and training in using the system. At the end of the meeting, the Chief Ranger successfully created a new account, registered and configured one of their three test systems. He was comfortable with configuring the remaining two systems and instructing other staff on their use.

In an afternoon session, several more staff attended to discuss the system, its possible uses, and needs for adaptation. Several questions arose and were captured for inclusion in training materials and website on-line help.

Question	**Answer**
Do you get notified when batteries are dying?	Yes
Can the antenna can be painted?	Yes
Is there an ongoing fee for the satellite system?	Yes, approximately $250 per year
For the break beam sensor, how do you avoid false positives?	False positives can arise with large animals. Several "smarts" in embedded in the firmware to avoid false positives, such as a minimum and maximum beam interruption time to avoid objects such as falling leaves or stationary objects blocking the beam. For installation, it is best to install both the infrared emitter and receiver on rigid structures at shoulder-height. (during the project, "dirty signal" detection was added to the firmware to dynamically adapt to conditions which

	might arise in false positives (e.g. snow or device misalignment).
Will the traffic pattern let you know what time each vehicle came through an area?	No (but later added as an enhancement).
Is there an external battery connector for longer life?	Yes
Would a single tree canopy obstruct the satellite signal	Yes, if it is a large tree

Meeting participants identified the several applicable cases for park protection, including entrance into sensitive sites, graffiti and other vandalism, stealing artifacts (from exhibits, surface collection), stealing antlers, off-road vehicles, and looting with a metal detector.

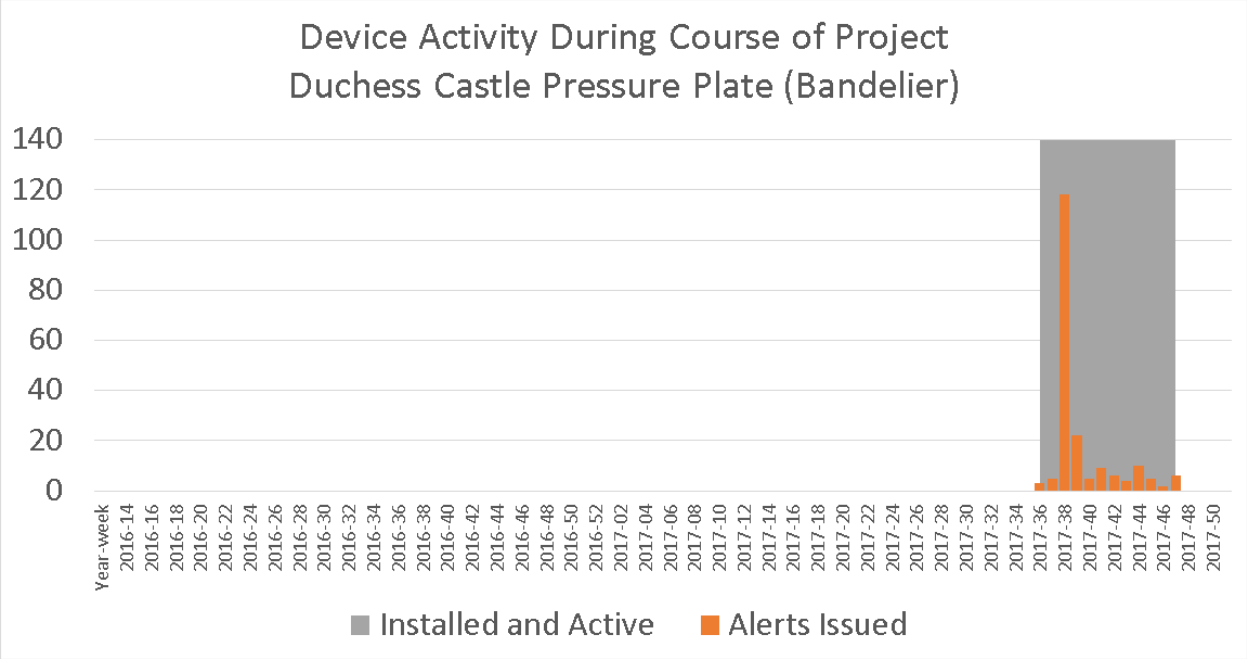
Bandelier National Monument has very limited cellular phone coverage. As a result, the park has recently acquired Delorme InReach devices which they can use while out on patrol. The handheld devices were acquired for volunteers to use while out in the park. Bandelier law enforcement staff described the need for evidence collection and proving a chain of possession for stolen artifacts. Violators need to be caught in the act and with photographic evidence or the prosecution may fail. For example, violators may claim that they bought the artifact, or found it at an area outside the park boundaries.

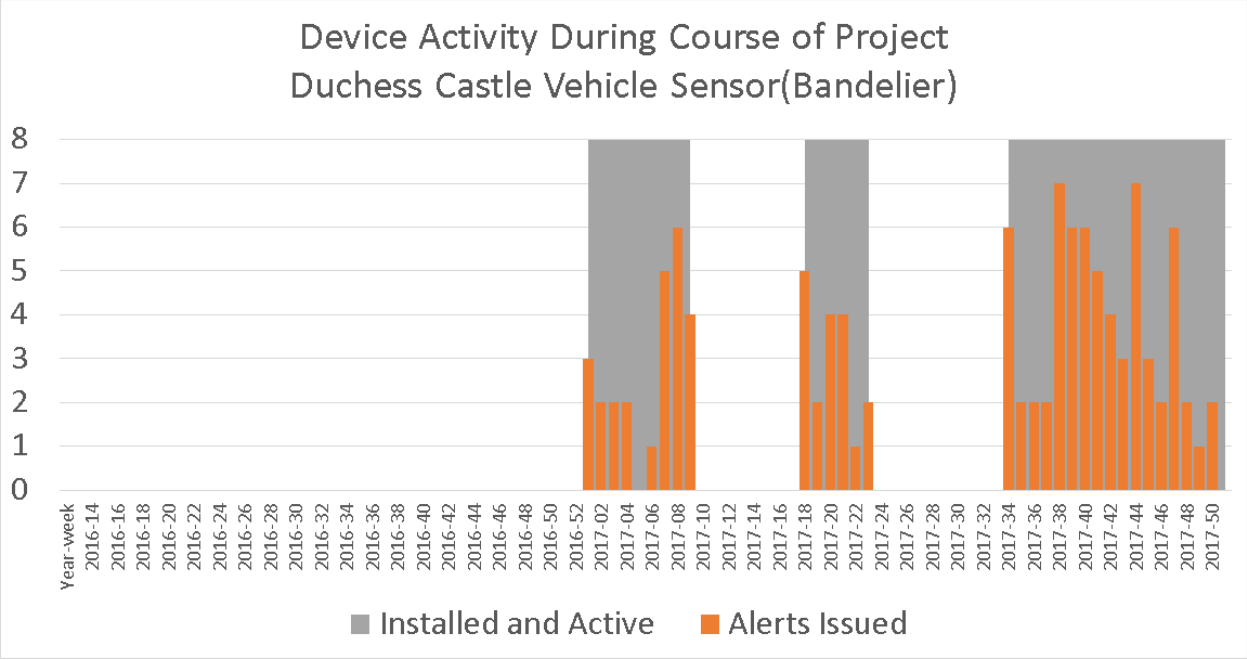
Bandelier staff brought the project team to the outdoor exhibits which they wish to protect. Daytime visitors prevented the installation of equipment, so mock installations and testing were performed near the training room. During the installation site visits, it was clear that the park needed to identify people traveling by foot. The nature of the trails, along the side of steep hills, would not permit the use of infrared break beam sensors since they require installation at either side of the trail, at shoulder height. The project team and staff discussed several options for installing equipment – either through hiding sensors and antennas in natural surroundings, or hiding the objects “in plain sight”. One example of this was suggested by the Chief Ranger: since the Iridium antenna resembles a site tag monitor, it could be painted and modified to look like one. Similarly, break beam sensor probes could be installed on the back of signage.

Bandelier National Monument staff identified several enhancements to the system including a footfall sensor; the ability to capture images and/or video; the ability to receive an image of surroundings when there is an alert, and; wireless sensors to cover large areas and avoid the need to disturb archeological sites with burying sensors.

As well, staff were interested in the use of sound sensors and the ability to send alerts directly to their handheld radios.

The staff identified the footfall sensor (to be known as the Pressure Pad) as the highest priority for Bandelier.





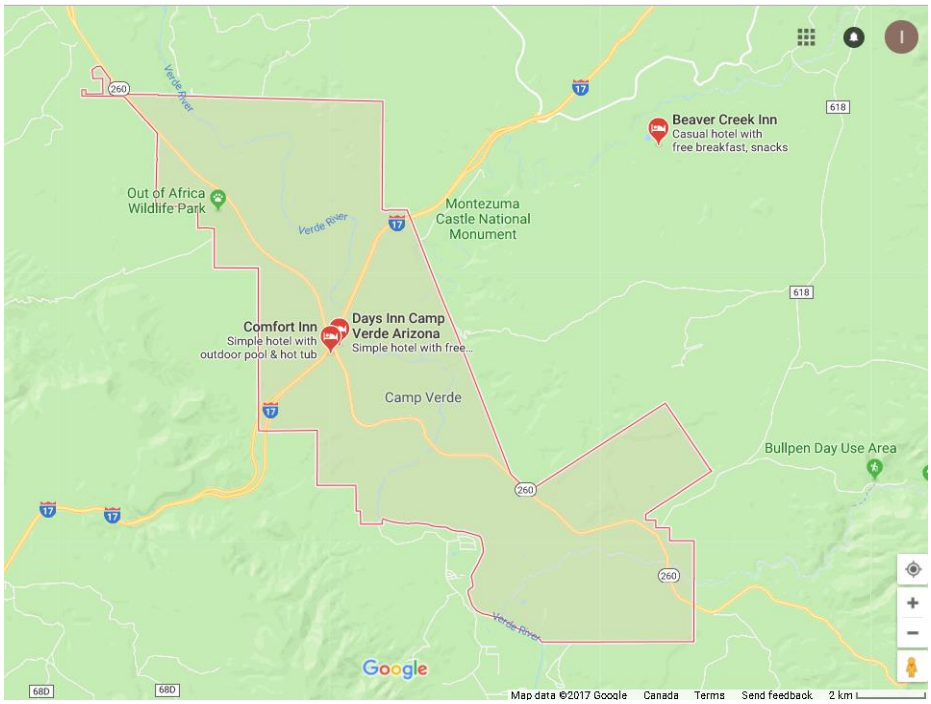
The Pressure Pad system was developed specifically for Bandelier National Monument. This park was the first to try the prototype sensor. An issue was revealed associated with moisture at one point (see spike in graph above).

During the course of the project one of three Bandelier systems was damaged by battery leakage. This problem was identified at other (non-project) sites and resulted in guidelines for avoiding battery

leakage including: using Energizer Lithium batteries which have anti-leak features, avoiding extremely hot direct sun conditions, not mixing old and new batteries, and avoiding keeping dead batteries in powered devices. The project team repaired and returned the system to the park.

The Bandelier survey participant indicated that he would upgrade and continue to use the system post-project if able to acquire funding for satellite costs.

Verde Valley Archaeology Center



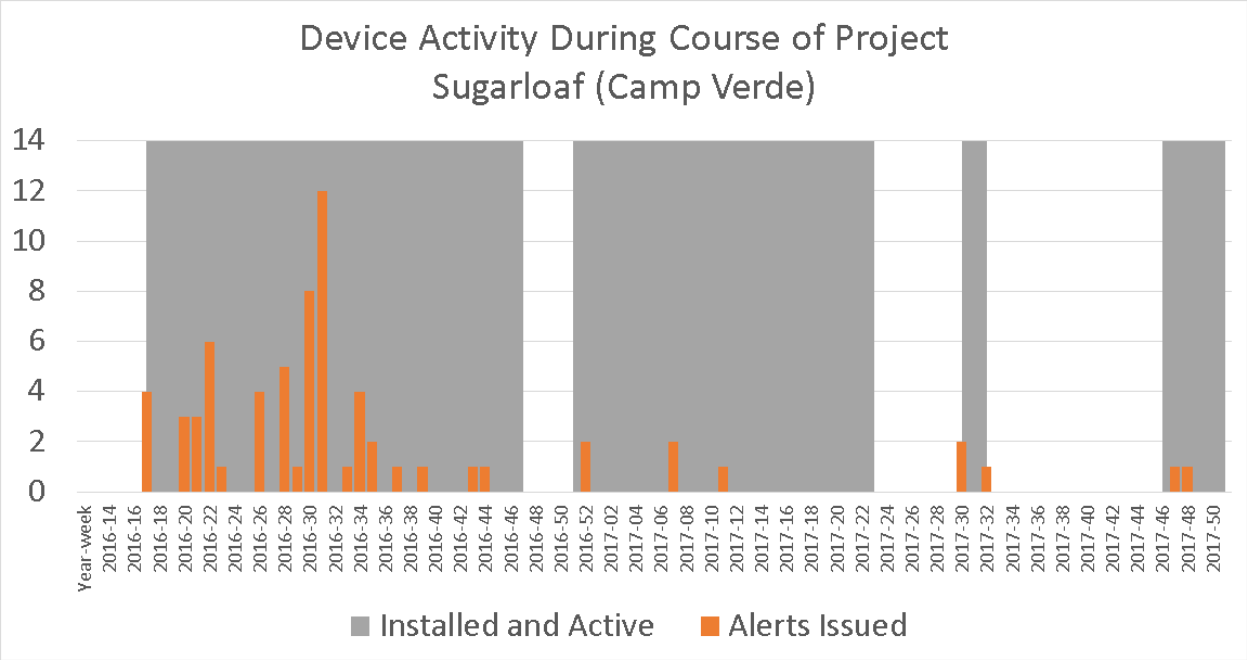
The project team met with participants from the Verde Valley Archaeology Center on Saturday Mar 19, 2016. Verde Valley Archaeological Center is the official onprofit partner of the National Park Service for Montezuma Castle and Tuzigoot National Monuments. This organization was included in the project because they represent one of many such partnership arrangements with NPS. Attendees include Kenneth Zoll (Executive Director), Todd Bostwick (PhD, Director of Archaeology) and Scott Newth (Technology Lead))

Meeting participants received an overview of the project, of the technology, and training in using the system. At the end of the meeting, attendees successfully set up and tested the equipment.

During the course of the overview and training, several issues arose and their resolution was integrated into training materials and website on-line help.

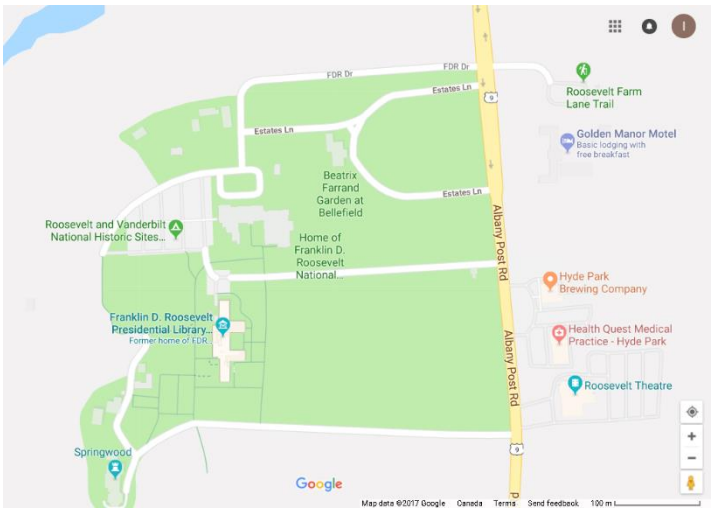
Question	**Answer**
Can you update the systems remotely?	Yes
How does the InReach handheld unit notify you of an intrusion?	Similar to a text message
How deep can the base unit be buried?	Any depth, but the antenna must be exposed.
Have you used the technology in an archaeological setting previously?	No
Is the Base Station waterproof?	Yes
How deep should the vehicle sensor be buried?	About 6 inches, cover with fine dirt instead of sharp rocks
Who gets check-in and alert messages?	Anyone identified by the user in a distribution list (unlimited)

Verde Valley Archaeological Center participants were very active during the project. They followed up on approximately 70% of alerts within 24 hours and had the most "up-time" of any participating park. During the project, issues were experienced with the base station internal clock and battery voltage levels. The system was replaced with no subsequent issues.



During the project evaluation webinar, Verde Valley Archaeological Center participant Scott Newth identified that in order to be used as a deterrent the system needs to be accompanied with signage.

Home of Franklin D Roosevelt



The project team was unable to meet in-person with David Hayes (Chief of Resource Management & Facilities) but was able to meet via teleconference on December 12, 2016.

The Home of Franklin Delano Roosevelt site has periodic trouble with mountain bikers riding outside of permitted zones.

During the training teleconference, David Hayes gave his feedback on the system usability with the unique experience of having used the equipment with no in-person training. He felt that the instructions could be more like an IKEA instruction manual showing system assembly, parts list and labels. He noted that the website list of time-zones is quite long. Finally, he indicated that the "SMS" message delivery option would be more easily understood as "Text Message".

Home of Franklin Delano Roosevelt was able to get the system installed as a test to successfully send an alert message but did not have any significant period of time sending regular check-ins.

Technology Experiences

According to the survey of four participating parks, all respondents found the installation straight forward.

Survey Question	Responses
Did you find the training useful and adequate for installing the system?	Yes (4/4)
Was the product straight forward to install?	Yes (4/4)
Did you encounter any problems during installation?	No (3/4)

However, the use of the technology is dependent on co-ordination and co-operation of law enforcement staff who, in general, have many competing priorities. The following survey results on "Potential" describes how most participating parks will not continue the technology if there is an on-going cost. It is unknown whether this is an administrative issue or whether it is felt that the money is better spent elsewhere.

Potential	
Do you feel anti-trespass technology can be used effectively at archaeological sites to reduce vandalism and theft?	Yes (3/4) "Not yet. Too many false hits" (1/4)
What hardware improvements to the system can you suggest?	"photo (b/w) rendering of visitations sent via text" (1/4) "Pressure pad issues. Unable to effectively place break beam." (1/4)
What website improvements to the system can you suggest?	"Better GUI [Graphical User Interface]" (1/4) "Website is good" (1/4)
What new sensors would be useful?	"cameras, lights, motion detection" (1/4) "Metal on metal trigger (something moved off of a sensor or something along those lines)" (1/4) "Don't know" (1/4)
In the context of your organization, what is necessary for better adoption and use of this and similar technology?	"Simpler" (1/4) "limited applications in our area as access to sites is usually via several different areas." (1/4) "We have high traffic areas we monitor. We could incorporate the tech better with cameras." (1/4)
After the project closes, will you continue to use the system (monthly satellite fees of $20 / month will apply)	No (4/4) (with one caveat clarified below)
If no, can you explain why (cost, not useful to your organization, etc)?	"Not enough data to justify continued use" "Properties are owned by ... and they are not willing to pay $240 per year per site to protect them" "Unsure but I will try to get funds. I would like to use them. " (1/4)
If yes, ·Would you like to upgrade your system to the new wireless sensor version (no cost)?	Yes (1/4) No (2/4)

Adaptations for Archaeological Parks and Cultural Monuments

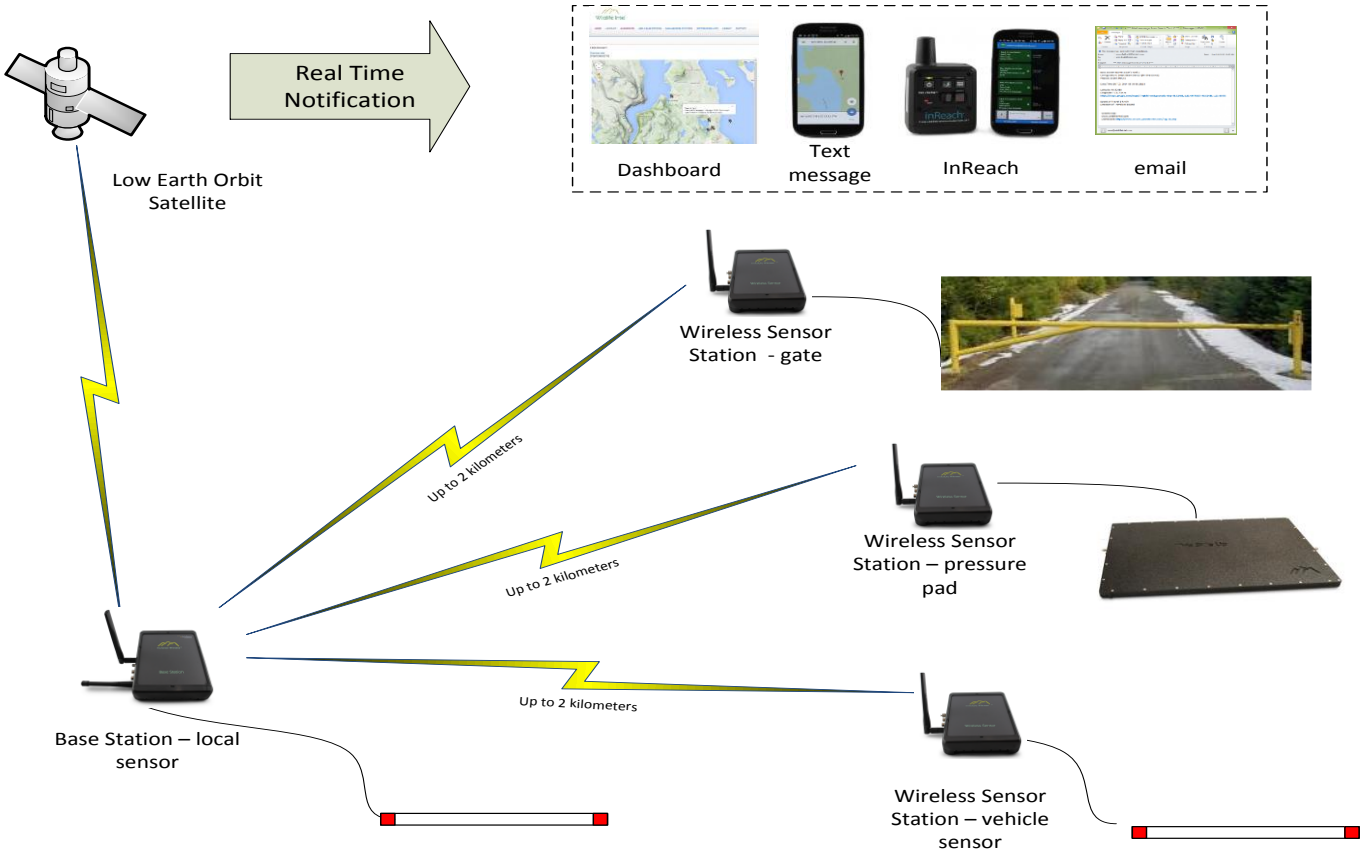
Participants identified a number of system improvements or desired features as identified above. The project team was able to incorporate most of these during the project period.

1. Wireless sensors – the major system change over the past two years. Trials on this new system are beginning
2. Improved user interface – the new wireless system also includes
3. Mobile friendly website – the website was converted to a mobile friendly, “responsive” theme
4. Pressure pad sensor – a new pressure pad sensor was designed, developed and trialed by Bandelier park and provided to Death Valley and Home of Franklin Delano Roosevelt.
5. Hourly traffic logs – this firmware change now allows users to see hourly patterns of traffic
6. Suspend alerts by time of day – this firmware change allows users to suspend alerts during, for example, visiting hours
7. Frequency limits on notifications – this firmware and website change allows users to set how frequently they would like to be notified of alert events.
8. Improved break beam battery pack – hardware is now smaller and more rugged
9. Product labeling – the new wireless system now has product labelling so that the user immediately knows, for example, which cable plugs into which port
10. Nicknames for SMS, InReach and email addresses – the monitoring website now allows nicknames to make message distribution easier to manage
11. Break-beam firmware improvements – now includes additional routines to avoid false positives (“dirty signal detection”)
12. Rigid L bracket for satellite antenna – users can now avoid an antenna cable altogether

The following section describes the more significant adaptations in detail.

#1 Wireless Sensors

The new anti-intrusion system supports up to ten wireless sensors, all connected to a single satellite communicator up to 2 kilometers apart. The following diagram illustrates how radio communications is used across several sensors.



#2 Improved User Interface

The new anti-intrusion system includes an on-board display and menu for more intuitive use.

#4 Pressure Pad Sensor

This new sensor was developed for archaeological and cultural monument sites where break beam systems will not work. The pressure pad detects sudden changes in pressure and is sized to recognize most stride lengths.

Conclusions

Specific Needs of Archaeological Sites and Cultural Monuments

Clearly the technology developed has application to archaeological and cultural monument site monitoring albeit with different contingencies than faced with many wildlife protection scenarios. Archeological sites in the southwestern USA often have open landscapes meaning that there are fewer trees and brush to hide sensors. We found that infrared break beam sensors were difficult to hide and mount at shoulder height. Buried sensors such as roadway vehicle sensors and pressure pads are much better suited to these open landscapes.

The open landscapes that characterized many of the participating parks are particularly well suited to satellite (and radio) transmission. Sky view needed for satellite transmission is readily available in contrast to available exposures in dense forests. The newly developed wireless sensors rely on line-of-sight radio communication and again are well suited to the open landscapes

We found that, in archaeological and cultural monument sites that accept visitors, just a short distance (a few yards) can mean the difference between detecting a violator and a rule-following patron. Consider, for example, the visitor who stays within cordoned areas versus the visitor who exits permitted access areas and enters a pueblo. In this scenario, detecting when visitors have gone outside of permitted areas is most important. The pressure pad was designed, developed and prototyped for this situation.

Finally, we noted that installations in archaeological and cultural sites often require permits. This can limit installation options and timeframes.

Park staff and volunteers are clearly very busy. Time to install devices – while only ½ day per system – was scarce. Using the technology to full advantage requires park staff to approach the task of monitoring potential park violators using this technology as a priority. To avoid “throwing technology at a process problem” integration of equipment and monitoring the data emanating from it would need to become part of operations priorities. This pilot assessment indicated that in the majority of cases implementation of this technology can provide a significant boost to site protection capabilities.

Appendix: Survey Results

Survey Question	**Participant Responses**
Current State	
How many incidents of looting and vandalism does your park experience each year? (order of magnitudes are acceptable)	"1-2" "2-4" "Unknown" "Unknown (several major incidents detected a year. Numerous small incidents)"
How many security staff does your park employ? (Full Time Equivalents)	0 (1 out of / 4 respondents) 4 (1/4) 5 (1/4) "Unknown" (1/4)
Usability	
Did you find the training useful and adequate for installing the system?	Yes (4/4)
Was the product straight forward to install?	Yes (4/4)
Did you encounter any problems during installation?	No (3/4)

Project Experiences	
Please describe your anti-trespass system installations (what did you want to protect, and how did you use the system to do that?)	"Restricted historic sites" "On trail to detect bicycle use" "two below ground metal detectors under pathways to 35 room pueblo archaeology site" "Used to detect and monitor activity in area with known vandalism/collection issues. Closure monitoring."
Which sensors did you select for your site(s)?	“Vehicle Sensor” (3/4) “Pressure Pad” (2/4) “Infrared Break Beam” (1/4)
In controlled tests, what percent of the time did sensors work to detect and notify? [%]	100% (1/4) 95% (1/4) “Unknown” (2/4)
About how many actual trespass alerts were issued?	"We received too many false hits to take them alas actual violations." "Hundreds" 0 20
What percent of alerts did your park security staff respond to? [%]	0% 70% <5% "Unknown"
How do you feel the technology best contributed?	"A better understanding of intrusions at non-public sites" (1/4) "A better understanding of visitor traffic" (1/4) "Not sure but we had no detections" (1/4)

Potential	
Do you feel anti-trespass technology can be used effectively at archaeological sites to reduce vandalism and theft?	Yes (3/4) "Not yet. Too many false hits" (1/4)
What hardware improvements to the system can you suggest?	"photo (b/w) rendering of visitations sent via text" (1/4) "Pressure pad issues. Unable to effectively place break beam." (1/4)
What website improvements to the system can you suggest?	"Better GUI [Graphical User Interface]" (1/4) "Website is good" (1/4)
What new sensors would be useful?	"cameras, lights, motion detection" (1/4) "Metal on metal trigger (something moved off of a sensor or something along those lines)" (1/4) "Don't know" (1/4)
In the context of your organization, what is necessary for better adoption and use of this and similar technology?	"Simpler" (1/4) "limited applications in our area as access to sites is usually via several different areas." (1/4) "We have high traffic areas we monitor. We could incorporate the tech better with cameras." (1/4)
After the project closes, will you continue to use the system (monthly satellite fees of $20 / month will apply)	No (4/4)
If no, can you explain why (cost, not useful to your organization, etc)?	"Not enough data to justify continued use" "Properties are owned by ... and they are not willing to pay $240 per year per site to protect them" "Unsure but I will try to get funds. I would like to use them. " (1/4)
If yes, ·Would you like to upgrade your system to the new wireless sensor version (no cost)?	Yes (1/4) No (2/4)

Other Comments	
Please state any unexpected benefits or issues which arose during the project which you feel are relevant to the study	"We had voltage measurement issues that required 3 battery changes and did not resolve the problem. Had to get a new system. Also, installing anti-trespass equipment w/o signs explaining of such is pretty worthless as a deterrent to would-be trespassers. We learned of the trespassers via the device, but without signage, it did not cut down on trespassing traffic." (1/4) "Battery corrosion. Lesson learned." (1/4)
I would like my responses to be anonymous for grant reporting	Yes (2/4)
	No (2/4)